A Two-Sided-Loop X-Ray Solar Coronal Jet and a Sudden Photospheric Magnetic-field Change, Both Driven by a Minifilament Eruption

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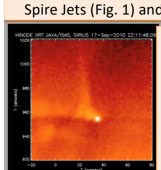
Abstract

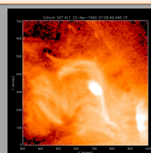
Most of the commonly discussed solar coronal jets are of the type consisting of a single spire extending approximately vertically from near the solar surface into the corona. Recent research of a substantial number of events shows that eruption of a miniature filament (minifilament) drives at least many such single-spire jets, and concurrently generates a miniflare at the eruption site. A different type of coronal jet, identified in X-ray images during the Yohkoh era, are two-sided-loop jets, which extend from a central excitation location in opposite directions, along two opposite low-lying coronal loops that are more-or-less horizontal to the surface. We observe such a two-sided-loop jet from the edge of active region (AR) 12473, using data from Hinode XRT and EIS, and SDO AIA and HMI. Similar to single-spire jets, this two-sided-loop jet results from eruption of a minifilament, which accelerates to over 140 km/s before abruptly stopping upon striking overlying nearly-horizontal magnetic field at ~30,000 km altitude and producing the two-sided-loop jet via interchange reconnection. Analysis of EIS raster scans show that a hot brightening, consistent with a small flare, develops in the aftermath of the eruption, and that Doppler motions (~40 km/s) occur near the jet-formation region. As with many single-spire jets, the trigger of the eruption here is apparently magnetic flux cancelation, which occurs at a rate of ~4x10^18 Mx/hr, comparable to the rate observed in some single-spire AR jets. This example of a two-sided jet, along with numerous examples of single-spire jets, supports that essentially all coronal jets result from eruptions of minifiaments, and frequently the eruption of the minifilment is triggered by magnetic flux cancelation. (Details are in Sterling et al. 2019, ApJ, 871, 220.)

1) Introduction: Two Types of Coronal Jets

Yohkoh/XRT revealed two kinds of coronal jets (Shibata et al. 1992, 1994; Yokoyama & Shibata 1995), Single-Spire Jets (Fig. 1) and Two-Sided Loop Jets (Fig. 2).



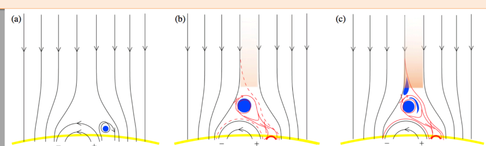
Single-spire jets have one spire, usually with a jet bright point (JBP) on one side of its base. The pictured event was studied by Sterling et al. (2015) using Hinode/XRT.



Two-sided loop jets have two "spires," with a middle bright point. This event (left) was studied by Shibata et al. (1994) using Yohkoh/SXT.

1a) Single-Spire Jets

Studies using *Hinode* and *SDO* show that many single-spire jets form when small-scale filaments (minifilament; blue circle) erupt into an overlying or far-reaching coronal field, creating the spire (orange) at an external reconnection site (upper red x in b and c). Reconnection internal to the erupting minifilament field (lower red x in b and c) produces a flare-like brightening (bold red semicircle) that appears as the JBP (Sterling et al. 2015). See Wyper et al. (2017) for numerical simulations of this idea. Other studies show that the minifilament's eruption is frequently triggered by magnetic flux cancelation (e.g., Panesar et al. 2016).



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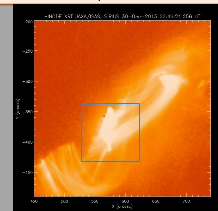
2) Instruments and Data

- Here we investigate a two-sided loop jet, using Hinode and SDO data.
- We examine an event of 2015 Dec 30 using Hinode XRT and EIS, and SDO AIA and HMI.
- XRT appearance is very similar to the Shibata et al. (1994) jet!

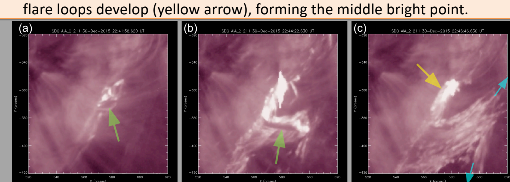


XRT (Be-thin) image. Box shows approximate FOV of images in the panels below.

3) Results.

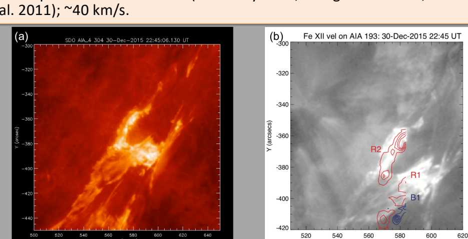
Two-Sided Loop Jet: Initiation in AIA 211

- (a) A minifilament (green arrow) can be seen starting to lift off the surface.
- (b) The minifilament is starting to strike overlying horizontal magnetic field.
- (c) The minifilament expands (unwinds?), with motions in two directions that form the two spires of the two-sided jet (blue arrows). Small-scale flare loops develop (yellow arrow), forming the middle bright point.



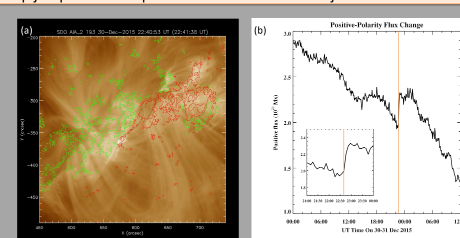
3a) Two-Sided Loop Jet: EIS Velocities

- a) AIA 304, when minifilament strikes overlying field.
- (b) Same time as (a), showing EIS Fe XII red- and blue-shifted velocities on AIA 193 b/w image.
- R1 and B1: Either counter streaming or untwisting (e.g., Williams et al. 2011); ~40 km/s.
- R2: supra-arcade downflows (McKinzey 2000, Savage et al. 2012; Warren et al. 2011); ~40 km/s.



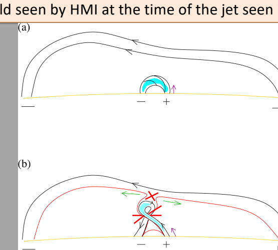
3b) Two-Sided Loop Jet: Magnetic Field Evolution

- (a) HMI line-of-sight (LOS) magnetogram on AIA 193 image; red/green = pos/neg polarities.
- (b) Evolution of isolated LOS positive-polarity flux in blue box of (a). The overall decrease is consistent with *flux cancelation*. The jet occurred at the time of the orange line. The insert confirms a sharp jump in the LOS positive flux coincident with jet onset.



3c) Two-Sided Loop Jet: Interpretation

- A twisted minifilament flux rope (blue) erupts (a), and impacts an overlying large, low-lying loop field (b).
- Reconnection at the contact point (top X in b) results in two jets flowing along the horizontal field (green arrows), forming the two jet spires. Reconnection between the legs of the erupting flux rope (lower X in b) produces the central bright point (red semicircle).
- In this drawing, SDO is viewing the region from the upper-left corner. Thus initially (the situation in a) the positive leg of the flux rope (purple arrow in a) does not point toward SDO. During the eruption however (b), it relaxes to point toward SDO. This causes the jump in the LOS magnetic field seen by HMI at the time of the jet seen in the previous slide.



4) Discussion

- We find that our two-sided loop jet is caused by a minifilament eruption, and that eruption is triggered by magnetic flux cancelation. This agrees with recent findings for single-spire jets.
- The apparent jump in the LOS HMI magnetic field is consistent with eruption of the minifilament field.
- Our two-spire-jet schematic picture is essentially the same as our single-spire-jet picture, where the right-side loop of the two-spire jet corresponds to the large external-reconnection loop of the single-spire jet, and the left-side loop of the two-spire jet corresponds to the open field in the single-spire jet. Thus the single-spire jet and the two-sided loop jet are the same phenomenon in different magnetic geometries.
- See Sterling et al. (2019) for further details on this event.
- Two subsequent studies are consistent with the results found here (Shen et al. 2019, Yang et al. 2019).

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